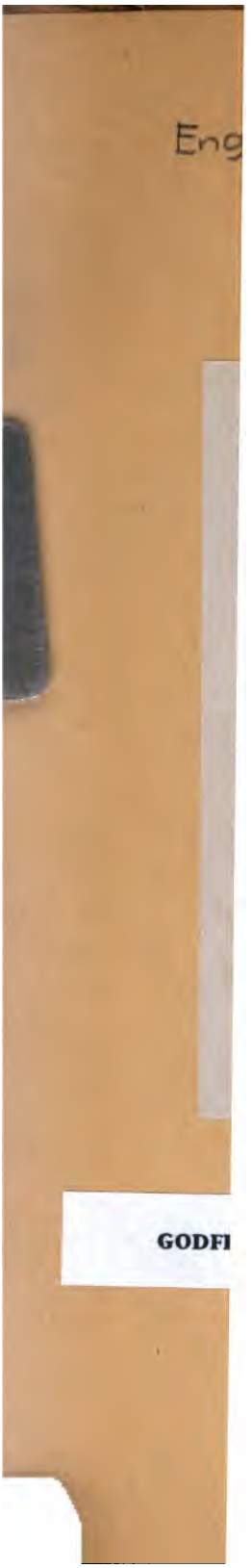
Eng
GODFI

REPORT

ON THE

WATERS OF THE HUDSON RIVER,

TOGETHER WITH AN

ANALYSIS OF THE SAME,

MADE TO THE

WATER COMMISSIONERS

OF THE

CITY OF ALBANY,

BY

C. F. CHANDLER, PH. D.,

PROFESSOR OF ANALYTICAL AND APPLIED CHEMISTRY, SCHOOL OF MINES, COLUMBIA COLLEGE.

MAY 15, 1872.

ALBANY:
WEED, PARSONS AND COMPANY, PRINTERS.
1872.

REPORT.

SCHOOL OF MINES, COLUMBIA COLLEGE,
NEW YORK, *May* 15, 1872.

To the Board of Water Commissioners of the City of Albany:

GENTLEMEN:

In accordance with your request, I have made a careful examination of the water of the Hudson River, at Albany, with reference to its possible use for the city supply, and I have the honor to submit herewith the results of my investigation.

My attention was first directed to the sample of water taken from the river outside the Pier, opposite Quackenbush street, on the 14th of March, by Mr. Carpenter, and forwarded to me for analysis.

The suspended impurities which rendered the water turbid, being temporary in character, were allowed to subside; the clear water was then found to contain the following substances in one United States gallon, of 231 cubic inches. An analysis of the Croton water is presented at the same time, for comparison.

ANALYSIS OF THE WATER.

	Hudson River.	Croton River.
Chloride of Sodium	0.361 grains.	0.402 grains.
Chloride of Magnesium	0.157 "	.....
Sulphate of Potassa	0.076 "	0.179 "
Sulphate of Soda	.....	0.260 "
Sulphate of Lime ($CaO,HO,2CO_2$)	0.980 "	0.158 "
Bicarbonate of Lime ($MgO,HO,_2CO_2$)	4.165 "	2.670 "
Bicarbonate of Magnesia	1.397 "	1.913 "
Silica	0.408 "	0.621 "
Alumina and Oxide of Iron	0.070 "	a trace.
Organic and Volatile Matter	0.699 "	0.670 "
Total	8.313 grains.	6.873 grains.
Hardness	3°.35	2°.51

The above figures represent the compounds as they are believed to exist in solution in the water. Owing to certain decompositions which take place on evaporation (the escape of a portion of the carbonic acid of the bicarbonates, etc.), the residue obtained by evaporating a gallon of water is somewhat less in quantity.

RESIDUE OF EVAPORATION.

	Hudson River.	Croton River.
Inorganic Matter	5.424 grains.	4.110 grains.
Organic and Volatile Matter	0.699 "	0.670 "
Total solids per gallon	6.123 grains.	4.780 grains.

The substances enumerated above must be considered with regard to their influence upon the fitness of the water for (1) washing and manufacturing purposes, (2) culinary uses, (3) drinking purposes. It should first be noticed, however, that the Hudson river water compares very favorably with the Croton in purity, the total difference per gallon being only 1.54 grains.

FOR WASHING AND MANUFACTURING PURPOSES.

The substances which render water objectionable for washing are suspended impurities and the salts of lime and magnesia. The former are deposited in subsiding reservoirs, and are not often present in the water supplied to consumers. When it is not possible to store the water a sufficient length of time to permit these impurities to settle, they may be easily removed by filtration, either on a large scale by the water companies, by filtering beds of sand and gravel, or by each consumer by the small filters connected with the supply pipes of his house or factory. The salts of lime and magnesia are chiefly objectionable on account of their action upon soap. Water containing them in considerable quantities are called *hard*, waters free from them are said to be *soft*. The hardness of water is measured in degrees by a soap test. Each degree represents the number of grains of carbonate of lime in a gallon of water or its equivalent in sulphate of lime or carbonate of magnesia.

For each degree of hardness, a gallon of water will destroy about ten grains of soap, by forming an insoluble lime soap which not only possesses no detergent properties, but separating as an insoluble flocculent precipitate attaches itself to some extent to the clothes washed. Hard water is not well adapted for washing, as it not only destroys the soap but renders it difficult to wash the clothes as clean as when soft water is used. To wash clothes thoroughly, more labor is required with hard water, and the clothes wear out more rapidly in consequence. Carbonate of soda may be added to hard water, to render the lime compounds insoluble and thus neutralize the hardness; this is less expensive than the equivalent quantity of soap. This loss of soap is by no means inconsiderable. The hardness of London water averages about 14°, so every gallon destroys about one-third of an ounce of soap. Galloway estimated that the people of London spend annually £63,000 for soap and carbonate of soda to neutralize the hardness of the water used in washing. Bateman fixed the saving to the people of Glasgow, on the introduction of the soft water of Loch Katrine in place of the hard waters previously used, at £36,000 per annum.

Next to washing the most important application of water, for which the question of hardness must be considered, is the supply of steam boilers. Hard waters deposit an incrustation or scale, composed of carbonate of lime and magnesia, and sulphate of lime, as a lining in the boilers, sometimes more than an inch in thickness. Being a poor conductor of heat this scale makes it necessary to use an increased quantity of fuel under the boiler, thus augmenting the running expenses of the establishment. It was estimated by French engineers that forty-five per cent of the fuel used in their locomotives could be saved by using soft water. In addition to this, it is found that the incrustations cause the boilers to burn out more rapidly, thus making more frequent repairs necessary and causing them to wear out sooner.

The Hudson river water is comparatively free from the lime and magnesia compounds, exhibiting only 3°.5 degrees of hardness. Consequently it may be freely used for washing and for supplying steam boilers, without causing the undesirable results which follow the use of hard water.

For Culinary Purposes.

Hard water is not well adapted for the preparation of food. Much sulphate of lime in the water makes it impossible to boil vegetables tender, and it is found that the use of hard water is attended with a considerable waste of tea, the lime salts making it more difficult to extract its soluble constituents. On the other hand, water entirely free from lime salts extracts too much of the bitter principles which seriously impair the flavor of the infusion. Four or five degrees are said to secure the best flavored infusion of tea. Bateman estimated that water as pure as that of Loch Katrine would save the people of London £400,000 per annum in soap, soda, tea, coffee, and chemicals. The Hudson river water contains such a trifling quantity of sulphate of lime, and is so soft, that no objections can be urged against it for culinary purposes.

For Drinking Purposes.

For drinking purposes it was formerly supposed that while the lime and magnesia compounds enumerated as occurring in the Hudson river water, and which are found in almost all river, pond and well waters, are not absolutely injurious in moderate quantities, it was nevertheless desirable that water for domestic use should be as free from them as possible; and the choice between two or more sources of water was decided by the relative amounts of these substances present.

More recent investigations have shown that moderate quantities of these compounds are actually desirable, at least this is claimed by some of the most distinguished authorities in England, where the subject of water supplies for cities has been most carefully studied. Dr. Letheby has carefully examined the connection between the quantities of lime and magnesia salts contained in the waters used in sixty-five English and Scotch cities and towns in connection with the rates of mortality. For convenience of comparison the waters are rated according to their hardness, represented in grains per gallon of carbonate of lime or its equivalent in soap destroying compounds.

TABLE SHOWING HARDNESS OF THE WATER SUPPLY AND THE DEATH RATES.

Hardness.	Number of towns.	Average death rate per 1,000.	Average hardness.
Over 10°	25	21.9	16.
10° to 6°	17	24.9	8.
6° to 2°	15	26.3	3.8
2° and under	8	28.5	1.3

It would certainly appear from these figures, that waters containing earthy salts in considerable quantities are preferable to very soft waters. Even if this generalization of Dr. Letheby is not fully sustained, the old theory, which demanded the softest water possible, can hardly stand in opposition to these facts. The potassa and soda salts are entirely unobjectionable for all purposes, unless their quantity is many times larger than in the Hudson water.

The organic matter contained in water really demands the closest scrutiny, however. Under the name of organic and volatile matter, chemists group together a great variety of substances some of vegetable, some of animal origin; none of which have been individually investigated, including the comparatively harmless products of decay from the forests and swamps, and the offensive sewage which is loaded with foulness. As the total quantity of these organic matters of all kinds rarely exceeds one or two grains per gallon, it is practically impossible to separate the different compounds from each other, to determine their individual properties. For this reason little is known of their exact nature. It is well established, however, that those of vegetable origin are generally harmless, while those derived from animal sources, as from sewage, though highly dangerous in certain stages of decomposition are speedily changed by the oxygen held in solution in running water, to forms which are innocuous. Dr. Taylor stated before the parliamentary commission that "organic matter in water is only offensive while in process of decay, when this operation is completed it ceases to be offensive." It is only when this matter is present in excessive quantities, and the water either for this

reason or from imperfect aeration fails to oxidise and destroy the noxious compounds, that its effect is to be feared.

In extreme cases this organic matter may render water very offensive to taste and smell, especially when it is allowed to remain at rest in close vessels in a warm situation. There are unfortunately no really satisfactory tests that can be applied to a sweet water, free from taste and smell, to determine, with absolute certainty, the absence or presence of *small* quantities of noxious organic substances. In the case of the Hudson river water no indications of the presence of any such objectionable matter could be detected. While the water is somewhat turbid at the present time, as all river water is liable to be in the Spring, or under certain conditions of flood and drouth, I find it on standing to deposit the suspended matters, clay and alluvium, and to remain sweet and fresh, without acquiring either the taste or odor which indicate objectionable matters. Moreover, the total quantity of organic matter is very moderate, and compares favorably with that found in the best waters of other cities. In the sample taken March 14, when the river was covered with ice, it amounted to but little more than two-thirds of a grain per gallon, almost exactly the same quantity recorded in the Croton. In the samples taken after the ice melted the quantity was somewhat larger, but in no case did it greatly exceed one grain.

In a river like the Croton, which flows through a region but thinly inhabited, and on whose banks there is hardly a village of any size, we are certain that no noxious substances can render it unwholesome, though it may occasionally be rendered unpalatable by the decay of an excessive growth of aquatic vegetation, or infusorial life. Or, as at the present moment, by the scouring of the water shed in the Spring, by the waters which owing to the late escape of the frost from the ground, after an open winter, have flowed over the surface, instead of filtering through the gravels and sands to reach the streams.

The case is different however with a river like the Hudson, on whose banks flourish frequent villages, towns, and even large cities.

When the water fails to exhibit any excessive quantity of organic constituents, or to manifest those peculiar properties which indicate foulness, we are compelled to resort to other means before we can safely pronounce upon its fitness for

domestic use. We must either rely upon experience, or in the absence of a sufficiently extensive use of the water in the past, we must judge by the experience obtained from other rivers on which similar conditions prevail. The water of the Hudson has been, and is now, freely used by boatmen and on the steamboats, and by all who are so situated as to make it the most convenient source of supply, and no complaints are known to have been made with regard to its quality, nor has any one suspected it of being in the least unwholesome.

This experience is, however, so limited that we must seek in other localities for analogous conditions and satisfy ourselves by comparison with regard to the probable quality of the Hudson river water. There is no locality in the world to which we can turn with a greater certainty of finding a full array of facts and opinions than have been accumulated in England with regard to the Thames, which supplies more than one-half of the water used in London. I propose therefore to institute a comparison between the two streams in regard to the sources of defilement, volume of water, natural facilities for aeration and spontaneous purification, and then to present the opinions of the best authorities as to the quality of the Thames water.

Extent and Population of the Drainage Area of the Thames.

The area of the Thames water shed, above the point at which the water companies take their supply, is 3,676 square miles, or 2,352,640 acres, while the population is about one million.

There are three large cities, Oxford, Aylsbury and Reading, each with a population of over 25,000. The cities next in size are Windsor, Guildford and St. Albans, containing from 7,600 to 9,500 inhabitants. Besides these there are thirty other towns containing from 2,000 to 7,000 inhabitants each. The average for the entire area is one person to about 2⅓ acres, or 272 to each square mile.

The rain fall in this area averages 27.2 inches, and it is estimated that one-third of this quantity flows down the Thames at Kingston. The average flow at Kingston, for five years, was 1,350,000,000 gallons daily, equivalent to nine inches of rainfall. In very dry seasons, the flow is reduced to 350,000,000 gallons.

Extent and Population of the Drainage Area of the Hudson River.

The Hudson river at Albany, including the Mohawk, drains an area of about 7,000 square miles or 4,500,000 acres, while the population is about 400,000.

On the Hudson there are two large cities, Troy and West Troy, containing 46,421 and 22,616 inhabitants, respectively; and one on the Mohawk, Utica, with a population of 28,798. There are fourteen other cities and towns on the two rivers, with from 2,000 to 15,000 inhabitants each. Still the greater part of the population is scattered in villages, hamlets and isolated farm houses.

Very few of these towns are provided with sewers, consequently very little of the unoxidized organic matter of sewage finds its way into the streams. In this respect, differing from the English towns on the Thames, where, until recently, the sewage was poured directly into the river.

The average for the entire area is about eleven acres to each inhabitant, or fifty-seven persons to each square mile. The average volume of the Hudson at Albany, was estimated by Mr. Sweet to be 618,111 cubic feet per minute, equal to an average daily flow of 6,677,000,000 gallons. The minimum being 1,829,000,000 in July, and the maximum 12,330,000,000 in March.

Comparison of the Hudson with the Thames.

	Hudson.	Thames.
Population of the water shed.....	400,000	1,000,000
Population per square mile.....	57	272
Average daily flow.....	6,677,000,000 gals.	1,350,000,000 gals.
Minimum " "	1,829,000,000 "	350,000,000 "

It thus appears that the population of the Thames' area is two and one-half times greater than that of the Hudson, and five times more dense, while the flow of the Thames is only about one-fifth that of the Hudson. Comparing the population with the flow of the rivers, we find that, in the case of the Thames, it is twelve and one-half times greater than in the case of the Hudson.

Healthfulness of the Thames' Water.

There have always been alarmists who have excited the fears of the people of London with regard to the condition of the water supply, and there are still those who believe that it is not safe to drink it. From time to time parliament has caused committees to examine into its condition, and a royal commission has had the matter under consideration for several years. A few quotations from the reports of these bodies and from other sources will serve to show the opinions of those who are most entitled to respect.

Opinion of the Committee of the House of Commons and the Chemical Commission.

A special committee of the house of commons considered the report of the royal commission of 1850 on the water supply, and employed three of the most distinguished chemists of England to aid them in their investigation. Prof. Graham, Master of the mint; Prof. W. Allen Miller, and Prof. Hoffman. The final verdict of the committee is embodied in the following sentence: "The Thames' water is perfectly wholesome, palatable and agreeable; uniform, plentiful and safe in use."

The chemical commission, composed of the chemists above mentioned, reported as follows:

"As the main drain of a large and populous district, the Thames becomes, at all seasons, polluted by the sewerage of several considerable towns, and by the surface drainage of manured and ploughed land; at the same time, we doubt whether the existence of organic contamination from town drainage is at present perceptible in the Thames above the reach of the tidal flow (*i. e.*, above London), or amounts to a sensible evil. The indefinite dilution of such matters in the vast volume of the well aërated stream is likely to lead to their destruction by oxidation, and to cause their disappearance. The river may reasonably be supposed to possess, in its self-purifying power, the means of recovery from an amount of contaminating injury equal to what it is at present exposed to in its higher section (*i. e.*, above London)."

In 1867 another committee of the house of commons inquired into the water question. After listening to the testimony of

a number of the most competent experts they declared that "They were satisfied with both the quantity and quality of the water supplied by the river Thames." The water of the Lea they found "naturally not only wholesome, but comparing favorably with that supplied to other places."

While these extracts represent the general verdict in favor of the Thames water, there were still, and there are even now, a few who dissent from this opinion. The most prominent of these is Dr. Frankland, professor of chemistry at the Royal Institution.

Dr. H. Letheby, the medical officer of health for the city of London, thus criticises his opinion:

"In reply to your letter of the 5th instant, I have to state that I cannot agree with Dr. Frankland that the water of the Thames, after receiving defæcated sewage water, is unfit for domestic use; for, after a large practical acquaintance with the subject as it is observed in the principal streams and rivers of England, I have arrived at a very decided conclusion that sewage when it is mixed with twenty times its volume of running water and has flowed a distance of ten or twelve miles, is absolutely destroyed; the agents of destruction being infusorial animals, aquatic plants and fish, and chemical oxydation."

Dr. Frankland seems to contradict himself, for in an article in the Quarterly Journal of Science of 1867, he says:

"The population in the basin of the Thames above where water is taken is 1,000,000, the drainage of some 600,000 of whom is poured into the river, the sewage is so thoroughly oxidised that no trace of it can be detected in an unoxidised state. The average flow of the river at the point where the companies take ther supply is 800,000,000 gallons daily. The sewage contained would be $\frac{2250}{100000}$."

Report of the Royal Commission.

In 1869 the royal commission on the water supply of the metropolis made their last report, which was published in a folio volume of 128 pages, and was accompanied by a volume of minutes of evidence of 488 folio pages, and an appendix of 144 pages with numerous maps, etc. In this report they say:

"But though for these reasons we believe that the organic contamination of the Thames is much less than is commonly

imagined, still it would be sufficient to do great mischief, were it not for a most beneficial provision of nature for effecting spontaneously the purification of the streams. Some of the noxious matter is removed by fish and other animal life, and a further quantity is absorbed by the growth of aquatic vegetation; but, in addition to these abstractions, important changes are effected by chemical action. The organic compounds, dissolved in water, appear to be of very unstable constitution and to be very easily decomposed, the great agent in this decomposition being oxygen, and the process being considerably hastened by the motion of the water. Now, as such waters always contain much air dissolved in them, the decomposing agent is ready at hand to exert its influence the moment the matter is received into the water; in addition to which the motion causes a further action by the exposure to the atmosphere, and when (as in the Thames) the water falls frequently over weirs, passes through locks, etc., causing further agitation and aëration, the process must go on more speedily and more effectually. The effect of the action of oxygen on these organic matters, when complete, is to break them up, to destroy all their peculiar organic constitution, and to re-arrange their elements into permanent inorganic forms, innocuous and free from any deleterious quality. This purifying process is not a mere theoretical speculation. We have abundant practical evidence of its real action in the Thames and other rivers."

In order to present more in detail the opinions of the scientific advisers to the commission, I will present a few extracts from the testimony.

EXTRACTS FROM THE TESTIMONY BEFORE THE COMMISSION.

Testimony of Sir Benjamin Brodie, Professor of Chemistry in the University of Oxford.

"Oxidization is constantly going on in the soil and in the river; and, therefore, there must be some point at which the perfect destruction or oxidation of its animal matter must take place. What I think is much more important still is another point, namely, the great dilution of the material, and I should

rely upon the dilution quite as much, and more, than upon the destruction of the injurious matter; supposing the sewerage of a large town, as Oxford, pouring into the river there are numerous feeders and tributary streams to the river, which effectively dilute the sewerage. The sewerage is gradually getting less and less, and, therefore, its noxious character diminishes, and ultimately disappears."

TESTIMONY OF DR. ODLING, PROFESSOR OF CHEMISTRY AT THE ROYAL INSTITUTE AND AT ST. BARTHOLOMEW'S HOSPITAL.

"Q. Has your attention been directed to the important principles of the self-purifying processes which are going on in the rivers running at a given velocity?" A. "Yes, it has." Q. "You will understand my question is not referring to sluggish waters, but to the rivers where the body of water would become exposed to the action of the atmosphere as it passes along?" A. "You may see in many rivers, even sluggish rivers, having sewerage discharged into them, that for a mile or two the appearance of the river is affected by the sewerage, but beyond a certain distance there is no recognizable effect at all, the weeds are perfectly clear and perfectly healthy."

TESTIMONY OF DR. MILLER, PROFESSOR OF CHEMISTRY IN KING'S COLLEGE, LONDON.

"Q. Are you of the opinion that water once contaminated with sewerage can never be considered a safe water afterwards?" A. "I think experience is quite against that, I think it is safe, evidence shows that it is safe in the majority of instances. There may be cases in which danger is produced." Q. "Have you made any experiments upon the power of water, in a given course, to oxidize organic matter?" A. "I ascertained a remarkable result in 1859 upon the river; I took specimens of the water at Kingston, at Hammersmith, at Sommerset House, at Greenwich, at Woolwich, and at Erith on the same day, and I examined the quantity of oxygen which the water contained at all those different points. I found the quantity of oxygen at Kingston was the normal or ordinary or normal proportion,

at Sommerset House it was much diminished, at Greenwich the whole of the oxygen had disappeared, at Woolwich it was in much the same condition, at Erith it was very much improved, showing that this diminution of oxygen had been produced by the action of the water, contaminated with the sewerage of the London district, and that as it passed lower down the oxygen was again absorbed from the air. And again it became diluted with a large volume of water from below, from other sources, the Lea, the Ravensbourne, and other tributaries, and in this manner the water had again become oxidised. I look upon this as a direct proof of the effect of oxygen in destroying those organic contaminations which are thrown into the river."

TESTIMONY OF DR. PARKES, PROF. OF MILITARY HYGIENE OF THE ARMY MILITARY SCHOOL AT NETLEY.

Q. "Have you observed in a case where sewerage has been discharged into a river, that, after running three or four miles, the effect of the sewerage has been destroyed?" A. "Yes, we have that, in the case of the Southampton water supply. Some sewerage passes into the Itchen river, but it is quite destroyed by the time the water is distributed in Southampton, at least there is no detectable quantity." Q. "What is the distance?" A. "The distance is six or eight miles. I could not undertake to state the distance in which water would purify itself in that way, but there is no doubt that it does purify itself, although in what distance, or in what time, or under what precise circumstances, I could not say."

TESTIMONY OF MR. LEACH, ENGINEER TO THE THAMES CONSERVANCY BOARD.

Q. "How soon, in your observation, is the effect of sewerage destroyed by its flow and admixture with the waters?" A. "At Windsor it is discharged into a most unfavorable point in the river, where there is little or no stream at ordinary times. The matter which is passed out of the drain floats about in the river there to a very great and very disgusting extent. Two miles, or even a mile below, I could see no traces whatever of the sewerage."

TESTIMONY OF MR. HAWKSLEY, VICE-PRESIDENT OF THE INSTITUTE OF CIVIL ENGINEERS.

"The great complaint of London water is not the quality of the water itself so much as the polluted district through which it passes. That, I think, there is the greatest possible amount of misconception upon. There is a great deal of prejudice, not unnatural at all, but still amounting to prejudice upon that question. I believe, in fact I know, that the water of the Thames at Hampton is a very excellent water, very pure, very free from organic matter, and that what little organic matter there is, is of a very innocuous character."

Q. "What quantity of water, as compared with the volume of sewerage, is necessary for the purpose of breaking up into its original elements the sewerage which has been discharged into it?" A. "Generally about twenty to one; if the water flows rapidly and is very much disturbed so as to be continually receiving fresh oxygen, a smaller quantity, even twelve to one, will effect the process; if it proceeds very tardily it may take a little more, but usually twenty to one is perfectly abundant."

Q. "You remember, do you not, the original condition of the river at Leicester after receiving all the sewage of the town into it?" A. "Yes, perfectly well; at Leicester the water was as black as this ink; I do not mean to say that it was absolutely so thick, but, looking at it in a mass, it was as black as ink; nothing would live in it, and the smell was abominable, but by the time it got to Loughborough, twelve miles below, it was entirely restored to its pristine condition; you could stand on the bridge there and see the fish swimming among the beautiful reedy and other plants growing in the water just as in the purest stream; you could see every pebble at the bottom; that is an instance of the effect of oxidation."

Q. "The water has symptoms of returning purity, has it not, within four miles of Leicester?" A. "Yes, but not to the same extent as at Loughborough; the water was perceptibly impure, at the driest period of the year, down as far as Barrow; it could be just perceived there, but at Loughborough it was perfectly restored."

"There is no such thing as a particle of faecal matter put into the Thames at Oxford, finding its way down to Hampton

Court. It is all burnt up, in fact, by the combustion set up by the oxygen."

The Cholera Question.

It having been established with some considerable degree of probability, that the wells in certain parts of London had aided in disseminating the cholera poison during the successive visitations of that disease to the metropolis, an opinion had gained credence that the water of the Thames had contributed in no small measure to swell the awful list of victims who died from that disease, especially the water supplied by the East London water-works. Considerable testimony was therefore taken upon this point, the most important of which I will quote.

Testimony of Dr. Robert Argus Smith, Government Inspector of Alkali Works.

"If the germs pass into the rivers we do not know how far they may be carried. On the other hand we do not know that they ever can be carried in pure water, the dissolved oxygen may destroy them, as it unquestionably does putrescent matters. A positive proof of their transmission, in otherwise pure water is wanting. One might ask if a cholera germ in the water at Oxford would produce disease in London, and one might answer by asking if one cholera germ passing into the air at Woolwich would produce disease in Pimlico. This we do not know, but it seems probable that disease cannot be carried far by pure air, nor by water with much oxygen in it, which is equal to pure air. We are informed that the atmosphere is full of germs, but the evidence seems to be that it requires an unusual excess to attack us successfully, it seems to be a question of quantity."

Testimony of Dr. Letheby, Medical Officer of Health to the Corporation of London.

Q. "Taking the case of the cholera disease and the discharges from the human body being mixed up with the sewage, do you consider that any germs of that disease would be carried down in water?" A. "At the present moment, we do not know what the germs of disease are; if the germs of the disease be decomposing matter, then I do not think that they would exist in the water; but if the germs of the disease be living matter,

then it is possible that they may exist in the water, but as nobody, as far as I am informed, can tell us what the germs of cholera are, it would be premature for me or anybody to theorize as to the probability or the possibility of their existing in the water."

Q. "You are aware that it has been alleged that the main cause of the cholera, in the east end of London, was due to the water supply; do you entertain that opinion?" A. "No, I entertain the opposite opinion; it was a matter of duty with me to investigate the whole of the circumstances connected with the East London supply; in the first place it was supplied to the hospital to which I am attached, in the next place it was supplied to the eastern division of the city, where, as officer of health, it was my duty to look well into the matter, and in the third place I had a general interest in it scientifically, apart from any official connection with the subject, and I was very desirous to ascertain whether or not the water had been in any way concerned in the propagation of the disease; I therefore investigated it very fully."

Q. "Do you think the present supply of water to the London people is wholesome water?" A. "I do, a thoroughly wholesome water."

In his report on the sanitary condition of the city of London for the years 1866–67, Dr. Letheby is much more explicit in his discussion of the cholera epidemic of 1866. He says, on page 26, *et seq.:*

"But difficult as the problem is, to determine the exact value of the several circumstances which influence the severity of the disease, and especially those which give to it its marked local intensities, enough has been ascertained to indicate its general habits, and to show that it fixes itself at low levels in proximity to tidal rivers, among dense populations, that are living in ill-constructed houses, that are filthy, badly ventilated, badly drained, and generally defective of sanitary provisions; and the inference is, that the actual agent of cholera, be it what it may, can only find congenial conditions for its full development in damp and impure air."

"The theory of Pettenkofer is, that the essential conditions for the active manifestations of the disease are a porous soil, charged with excrementitious matter, and having a certain degree of hydration, as happens when the subsoil water has been just drawn off or is slowly retiring. All these conditions were

singularly coincident with the localization of the disease in the eastern districts of London; for the soil is gravelly, and therefore very porous to air and water, and it is largely charged with excrementitious matters derived from the local tide-locked sewers. It is also remarkable that for some months before the outbreak of the disease, the subsoil water had been gradually sinking in consequence of the drainage operations that were necessary for the construction of the main low-level sewer, and its branch to the Isle of Dogs. Now, according to Pettenkofer, it is exactly under these circumstances that a district is most liable to choleraic infection."

"Another theory which has been advanced to account for the local character of the outbreak is, that the water distributed to the infected districts was charged with choleraic matter; but looking at all the facts of the case, it is clearly evident that while none of them are discordant with Pettenkofer's theory, a large number are in open and direct antagonism to the water hypothesis. In point of fact it is necessary for the acceptance of such a speculation, not only that some clear proof should be given of the actual pollution of the water with choleraic matter, but also that the time of the outbreak throughout the infected district was coincident with the distribution of such water, and that it did not notably fail to produce the disease wherever it was sent. It is likewise necessary to show that the disease was strictly confined to the area of such distribution, and that the use of other water was not accompanied with like severe results."

"The alleged pollution of the water rests upon a series of assumptions, many of which are in the highest degree improbable."

"Apart, however, from the improbabilities of these assumptions, it is a fact that the water which is said to have been thus polluted did not produce its effects in the several districts to which it was distributed in any thing like uniformity of time or force. Suppose, by way of illustration, that alcohol or arsenic had become mixed with the water, and that on a certain day it was distributed to the public, we should expect to find that the action of the poison was not only manifested at the same time over the whole district of supply, but that it was confined to that district. Not so, however, with the water in question, for although it is not alleged to have been more than once polluted, yet the first effects in the several districts

occurred at long intervals; and there were many places to which it was distributed, where there was no sign of the disease; while others, which did not receive the water, were seriously affected."

"The dates of the outbreak of the disease in the districts supplied with the East London water were as follows: Bromley, June 27th; Poplar and Bethnal Green, June 30th; Shoreditch and Mile End, July 7th; Whitechapel, Stepney and St. George's-in-the-East, July 14th; and the East London Union, July 28th. A month therefore elapsed between the first outbreak of the disease in the several districts. It is, moreover, remarkable that, while it was so violent in many of the districts of supply, it was absolutely powerless in others. The death rate, for example, of Bethnal Green was 63 per 10,000 of the population; Whitechapel, 78; Poplar, 85; and St. George's in-the-East, 93; whereas the districts of Stamford Hill, Upper Clapton, Walthamstow, Woodford, Wanstead, Leytonstone, Buckhurst Hill, North Woolwich and Silvertown, were absolutely untouched by the disease, notwithstanding that they received the same water, and at the same time."

"More remarkable still, there were places in the very heart of the cholera field, and others close adjoining it, where the residents received the same suspected water, and used it freely without suffering in the least degree. In the Limehouse School, around which the cholera was frightfully fatal, there were 400 children who drank the same water as their neighbors, and yet there was not even a case of diarrhœa among them. In the London hospital, which is also in the heart of the cholera field, for it is surrounded by the districts of Whitechapel, Bethnal Green, Mile End, Old Town, and St. George's-in-the-East, there was an average resident population of 463 persons, and, although they drank freely of the unfiltered East London water, yet there was not a case of illness among them."

"Again, in the eastern division of the city of London, which adjoins the cholera field, the suspected water was supplied to 161 houses, with a population of about 1,732 persons, but except in one of these houses (20 Somerset street), which is on the boundary of Whitechapel, there was not a single death from cholera, and to verify this, I have obtained the addresses of all the persons who died in the cholera ward in Bishopsgate street. But, besides this, the disease was singularly

fatal in places where the suspected water was never used. In Crown Court, Blue Anchor Yard, Whitechapel, where the water supply is from the New river, the mortality was at the rate of 284 per 10,000. In Boar's Head Yard, of the same district, which is also supplied by the New river, the death-rate was 193 per 10,000; and indeed there are eighteen courts in Whitechapel, where none of the East London water was used, and yet, out of an aggregate population of 4,351 persons, there were 30 deaths from cholera, the mortality being at the rate of 69 per 10,000; that of the whole district being but 77."

"So that, on carefully examining the facts in their relation to the water theory, we find:

1. "That there is no proof whatever of choleraic pollution of the water."

2. "That there was no coincidence of time in the appearance of the disease in the several districts supplied with the suspected water."

3. "That numerous districts receiving the same water, but situated at high level, or placed beyond the cholera field, were entirely exempt from the disease."

4. "That even in the very heart of the cholera field, there were places receiving and using the suspected water with impunity."

5. "That other places not supplied with the water, but situated within the infected area, suffered equally with the neighborhood."

"I am far from wishing it to be thought that choleraic matter diffused through water will not produce disease. There is abundant evidence to show that it is often a prolific source of it; but I am anxious, in dealing with a question of so much public importance as the origin of the late epidemic, that none of the facts should be perverted, and that no hasty or ingenious hypothesis, without solid foundation, should take possession of the public mind. In the conduct of inquiries like this, there should be a calm, a full, and a candid examination of the facts; — we should endeavor to study the phenomena in a philosophical spirit, and apply to them the tests of sound induction; we should strive also to deduce from them such laws as will not only expose the nature of the malady, but will, at the same time, enable us to treat it successfully. Rash opinions, boldly asserted and tenaciously held, though they may force themselves on public attention, rarely lead to

useful results ; and while they have their hold on the popular mind they seriously hinder the progress of real knowledge."

These extracts are sufficient to indicate the opinions of the most eminent medical officers, chemists and engineers who have considered the fitness of the waters of the Thames, for supplying the people of London with wholesome water.

The verdict of the commissioners, after carefully and conscientiously weighing all the testimony presented, is as follows :

"The only point raised against the Thames water on the ground of organic contamination is of less positive character ; it is said that water which has been once contaminated with sewage, may still contain undecomposed organic matter, which, though inappreciable by the most delicate chemical tests, may still exercise prejudicial effects on the human system."

"The strongest form of this objection has reference to some opinions now prevalent, that certain forms of disease, such as cholera and typhoid fever, are propagated by germs contained in excremental matter ; and it is conceived possible that when matter of this kind once gets into streams, these germs may escape destruction and long preserve their dangerous character. It is said that no process is known by which such noxious material can be removed from water, and, therefore, it is argued, that water which has at any time been contaminated by sewage is henceforth unsuitable for domestic use. These opinions have been advanced by many eminent men of science ; they are worthy of respectful attention, and ought to operate as a constant stimulus to the most searching examination of the state of the water ; to the improvement of the modes and means of scientific analysis ; and to the diligent collection of medical data as to the effect of the waters upon the public health. But we cannot admit them as sufficiently well established to form any conclusive argument for abandoning an otherwise unobjectionable source of water supply ; we are of opinion that there is no evidence to lead us to believe that the water now supplied by the companies is not generally good and wholesome."

This report was made in 1869, and has been before the British public in an accessible form, in all its details, nearly three years, and its conclusions have been generally accepted. The most recent opinion I have seen in print is contained in a voluntary communication made by Dr. Alfred S. Taylor, the distinguished writer on chemistry, toxicology, and medical jurisprudence,

to the secretary of the West Middlesex Water Company, under date of March 7, 1872. He says: "Having during the last twenty-one years made analyses of the water supplied to my house by the West Middlesex Company, and compared it with numerous waters derived from rivers, springs and lakes in England and Scotland, I can confirm Dr. Whitmore's general conclusion that the water is good in quality and perfectly wholesome. This opinion is not based merely on chemical analysis, but on twenty-one years' experience derived from its use for all domestic purposes."

Conclusion.

I have selected as our chief basis of comparison the water of the Thames not only because it had been more carefully studied than any other source of city supply, but because it may be considered an extreme case. Notwithstanding the fact that one-half the supply of London, a city of considerably more than three millions of inhabitants, is supplied from it, while the river Lea furnishes nearly all the rest, London was said by Dr. Edwin Lankaster, coroner of Middlesex, to be the *healthiest city in the United Kingdom.* Had I not already presented a much more voluminous report than I intended, I should refer with some detail to the water supplies of several large continental cities, which are derived from large rivers flowing through much more populous regions, than that from which the Hudson issues, on the banks of many of which are cities much larger than any on your river. Tours is supplied from the Cher; Lyons from the Rhone; Toulouse from the Garonne; Angers and Nantes from the Loire; Paris from the Seine, the Canal d'Ourcq, and the Marne; Berlin from the Spree; Hamburg and Altona from the Elbe. The last named city, which is a suburb of Hamburg, takes its supply from a point eight miles below, when the water has received the drainage of 230,000 people. Most of the above mentioned rivers are among the largest streams in France and Germany, and flow through extensive and densely inhabited districts. Yet we have no reason to believe that there is any *permanent* defilement of the waters.

That there is generally no fear on the part of engineers, and those having charge of water supplies in American cities, is fully shown by the fact that many of our largest cities take

water from rivers. Hartford is supplied from the Connecticut; Jersey City and Trenton from the Passaic; Philadelphia from the Delaware and Schuylkill; Washington from the Potomac; Cincinnati and Louisville from the Ohio; and St. Louis, New Orleans and many other cities from the Mississippi. It has been suggested that the water of the Hudson might be contaminated by refuse chemicals from paper factories, woolen mills, print works and chemical works, already in existence or liable to be erected in future. In answer to this, I would say that the substances used in these establishments are, when diluted and mingled with a large body of water, entirely harmless. They consist chiefly of sulphuric, hydrochloic and nitric acids, chlorine, salts of soda, potassa and lime; which when mingled unite to form harmless salts, sulphates, chlorides and nitrates, most of which exists naturally in all river, pond and spring waters. I do not know of any chemical that can possibly be used in quantities sufficient to injure a stream of one-tenth the size of the Hudson, even at its lowest stage. In fact if such agents are thrown into the river, their action, if appreciable at all, will be exerted in contributing to destroy the organic matters derived from drainage.

With a view to making myself more familiar with all the circumstances surrounding the question of employing the water of the Hudson, I have carefully examined the shores of the river from Albany to above the bridge at Lansingburgh, collecting samples of water at some of the most important points.

Except at Troy, no sewerage of any consequence is discharged into the river; and even here, the volume of sewerage is so small in comparison with that of the river, that it does not make any impression upon it. None of those conditions of defilement, mentioned in some of the extracts already given, as occurring in the Thames above London, could be discovered. The water was never "black," "foul" or "offensive," as that which was so rapidly purified by the dissolved oxygen, between Leicester and Loughborough, and at Windsor.

I must not omit to call attention to the unusual combination of circumstances, by which the most complete aeration of the water is effected. Glens Falls, the falls of the Mohawk at Cohoes, and the State Dam at Troy, are the most effective means contrived by nature and art for preparing the water for the use of your citizens.

In the samples examined, the total number of grains of inorganic matter, and of organic and volatile matter as left by the evaporation were determined. The results are expressed in grains in one U. S. Gallon. The samples were collected April 3d.

Point at which Sample was Taken.	Inorganic matter.	Organic and volatile matter.	Total solids by evaporation.
1. Hudson River, above Union Bridge, at Waterford, above the Mohawk	3.733	1.166	4.899
2. Mohawk River R. R. Bridge at Waterford	5.249	1.399	6.648
3. Hudson River, at the State Dam	3.441	1.224	4.665
4. Hudson River, at Roy's Mill	4.849	1.166	6.015
5. Hudson River, at the upper opening of the Pier, April 3	6.182	0.933	7.115
March 14, 1872, opposite Quackenbush street	5.424	0.699	6.123
6. Present water supply from Rensselaer Lake	3.499	0.933	4.432

The most careful examination of the water has failed to reveal any thing to sight, taste, smell or analysis, which can be considered as throwing the slightest suspicion upon the purity of the water of the Hudson, or its fitness for supplying a perfectly wholesome beverage for the citizens of Albany. I am further confirmed in this opinion by the careful comparison of the river and its surroundings with the sources of supply in other cities in this country and Europe. I have no hesitation, therefore, in recommending it as a suitable and proper source of supply.

Respectfully yours,

C. F. CHANDLER, Ph. D.